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SPACE STATIONS AND SPACE CABIN TESTING

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For Earth Orbiting Space Stations neither expandable, extensible, nor converted propellant tanks appear as suitable for manned operations as a specially designed cabin regardless of the mission to be performed. While an interesting possibility, use of converted propellant tanks offer little advantage when viewed in the light of the overall space station system problem.

During the past two years studies have been conducted in some depth of the cabins associated with space station systems suitable for launch by Titan III C, Saturn IB, and Saturn 5 boosters. These studies have considered various crew complements, supporting ferries, and the effects of rotation for the generation of artificial "G".

Considering the requirements for integrating power supplies, thermal control, life support, attitude control, orbit propulsion, specific mission equipment, rendezvous, docking, communications, navigation, and crew creature comforts, the development of an efficient usable cabin becomes a task of significant proportions. Applying the constraints of removable and storable equipment to the fixed sizes and shapes of booster tankage makes the problem more difficult, the results less than optimum, and the increased cost substantial.

While cost is always a major consideration in space system design, it is pointed out that space station design reflects major systems costs as a second order function only. The primary influencing factor of space station systems cost is the expense incurred in the associated logistics system. Ferry vehicles and the boosters required to launch them as well as the expense incurred in tracking and recovery operations represent the major portion of total systems cost. Further, since these costs are directly proportional to crew size and tour of duty and since the cabin must reflect these considerations, it is only after a total resource limit is established that a cabin can be designed. At this point, optimization of crew time and volume, availability, reliability, use of existing subsystems equipment, and efficient performance of the primary mission become of major importance. The constraints imposed by the attempted use of existing tankage, therefore, far outweigh the advantage of maximizing the use of structure delivered in orbit.

In addition to booster capability and logistics costs the design of a space station systems is also quite obviously dependent upon the mission to be accomplished. The fundamental unknown to be explored by any early capability space station is man's ability to assist in the optimization of mission performance. Missions can be postulated by the score. They range from those of purely military nature, such as inspection or reconnaissance to scientific evaluation of the environment, astronomy, and others.

Examination of these missions using standard techniques available provide some basic information regarding the function of man in each, and some indication of the cost versus the return of performing these functions in a manned versus an unmanned mode. If all of the postulated crew functions for all of the postulated missions are now grouped by type, a listing as shown on Figure 1 is developed. Here then are the basic modules of crew function which can in the gross sense be selected and arranged for the performance of any military or scientific mission which might be considered.

In the same fashion, operation and maintenance of the station subsystems according to crew function have been grouped in Figure 2. Here the crew's presence has been considered in optimization, repair, selection, and use of the station "machinery" to best carry out the mission of interest.

At this point in the analysis of a manned space system one should be ready to trade-off the benefit of man's performance of the functions above versus the cost incurred by his presence. If this could be accomplished, then the fundamental decision of manned or unmanned system could be made based upon cost, effectiveness, and flexibility. Or if an a priori decision is made that the system is to be manned then the further trade-off of crew size as related to crew functions, degree of automation, crew effectiveness and reliability must be made.

Unfortunately, too little is known about man's performance of these functions in the space station environment to be able to predict with confidence his contribution to the overall system performance. This necessary understanding of man's performance relates not only to his tolerance to weightlessness but also to his ability to remain effective while operating at a high work load within the confines of a small cabin for long durations. Considering the subtle and highly complex nature of the interactions which effect man's performance and the difficulty in developing analytical criteria which is meaningful, the method which appears most suitable for establishing quantitative rationale of the relationship of man to system appears to be through the conduct of a series of high fidelity mission simulation experiments. Intelligently designed, these experiments can provide the basic information required to perform the trade-off studies necessary for space system design.

In March of 1963 General Electric's Missile and Space Division recognized this need for a method of highlighting the most critical factors for early systems design. As a result, a program was initiated for the development of the equipment, the techniques and the trained team which are required to perform laboratory simulation programs of this nature. Seven months later a 30 day closed environment test program was initiated using a four man crew for the prime purpose of evaluating their performance of space station related activities over this long duration.

In developing a program of this nature, it is necessary to review the parameters involved which may have a significant effect upon man's performance. These parameters are shown grouped in three major categories on Figure 3. Although weightlessness and the hazards associated with space flight cannot be simulated, faithful duplication of those remaining variables of total environment, duration, and crew activity can provide sufficient fidelity to the mission situation to permit confident measurement of the crew performance. While these measures will no doubt be somewhat affected by the introduction of zero "g" and fear in actual flight, the simulation conducted permits a much higher degree of confidence and understanding to be applied in relating a crew to a vehicle during the early design phases of system development.

In order to be meaningful, however, a simulation program must be structured as close to the real situation as possible. In all respects this test program used, as criteria and operations specifications, all of the applicable results of the space station study work which General Electric conducted during the past two years. Wherever possible, the equipment and the procedures used followed precisely these systems requirements and design criteria which were developed for an early capability, four to six man, earth orbiting space station.

In design of the test, it was recognized that human performance is always to some extent influenced by surroundings and the environment in which one lives. It was, therefore, necessary to faithfully duplicate a cabin which would be similar in all respects to the best projection of orbital operating hardware which existed. The cabin which was developed for this program is shown on Figure 4. It is 12 1/2 ft. in diameter, 24 ft. high and is separated into living and flight deck compartments.

The living compartment, Figure 5, was designed to convey a feeling of spaciousness and maximize storage volume for necessary equipment and supplies. Pull-out drawers contained food, drugs, and personal equipment for the 30-day mission. A small two cubic foot freezer accommodated diet supplements such as butter, several steaks, frozen apple pies, and tomatoes. A zero "g" type water dispenser was used for reconstituting freeze dried foods.

The center of most activity on the upper deck is the vehicle systems instrument panel shown on Figure 6. This panel is a result of a design study conducted for the development of the display and control requirements of a typical Earth Orbiting Space Station. Specific psychomotor tasks were located adjacent to the main instrument panel.

The cabin was installed as shown on Figure 7 in one of the three 39 ft. diameter space environment simulators now in operation at Valley Forge. Use of this simulator facilitated the contribution of conducting the test in an artificial atmosphere. The atmosphere chosen for evaluation was 7 psia composed of sea level oxygen with nitrogen as the diluent. This choice, the result of a detailed study relating structural penalty, leakage loss, fan power, fire hazard, and extra-vehicular operations appears to be the best compromise between engineering, physiological and operational requirements.

In order to evaluate the physiological effects, if any, of the 7 psia atmosphere selected, an exceptionally complete medical test program was designed and applied to each test subject.

The physiological tests made were separated into two essential categories based upon the equipments and skills required to take the measurements. Those measures requiring the facilities and techniques of medical research installations were generally classified as pre- and post-flight tests and are listed on Figure 8. The pre-flight tests were made to establish baseline data on each subject prior to entry into the cabin. A similar battery of tests was taken immediately upon exit from the cabin and before physiological re-adaptation to the earth-normal environment could have occurred.

The second category of tests included those which could be taken on a daily or periodic basis by the crew during the flight and which required equipment which could readily be expected to be contained within a space station.

These in-flight biomedical measurements were made on each crew member every day and included temperature, blood pressure, electrocardiogram, phonocardiogram and carotid pulse. In addition, pulmonary functions such as vital capacity and timed vital capacity were measured in order to gather the fundamental data required for an evaluation of crew health and well being.

The majority of the activities associated with these measures was contributed by the personnel and facilities of Temple University Medical Center. This joint participation of General Electric's space systems biologists and physiologists with Temple's clinical and research specialists in the areas of pulmonary, renal, and cardiovascular functions permitted an exceptionally extensive biomedical evaluation of the effects of an unusual environment upon man.

Twenty-four hour medical surveillance was also provided in the control room during the flight. Using closed circuit television and the communications system coupled with the daily in-flight data readouts, the doctors on duty were able to closely monitor each subject on a continuous basis. In this way, subjective data of health, well being, morale, and motivation were recorded and correlated with the individual diaries kept by the crew members.

The success of a complex program such as this depends, to a large extent, upon the performance of the team of supporting personnel. This is especially true of those individuals in the role of test monitors who control or have cognizance over all test activities on a minute-by-minute, day-by-day basis. The role of the monitors in this test was maximized in order that a high degree of task and equipment programming flexibility could be realized. For example, the monitors had control over all subsystem conditions, providing the opportunity to judge management performance. Each task was controlled individually, providing programming latitude in case of such things as scheduled emergencies, and equipment failures.

Psychological task panels, shown on Figure 9, were used for evaluation of crew performance. A total of eleven basic psychological tasks designed to probe many aspects of behavior were used for this evaluation. These involved several types of vigilance behavior, eye-hand coordination, higher order mental functions, and reaction time.

Each crew member had a four-hour "mission" period every day, at which time he would perform several of these tasks. Some of the tasks were performed daily, some every other day, and others every third day depending on the particular measure. The tasks were programmed to each individual relative to his work/rest cycle so that factors such as fatigue and alertness were balanced among the crew. This balanced design made it possible to either evaluate the effect of, or eliminate the effect of these factors in analysis of the data. These tasks were used in addition to the more complex operational requirements of rendezvous, docking, and subsystems monitoring.

Using a six degree of freedom real time analog program, the crew was required on a periodic basis to acquire an unmanned supply vehicle at a distance of 20 miles from the station and to fly a completely manual rendezvous mission using the displays shown on Figure 6. The task here was to successfully complete this maneuver and to bring the supply vehicle to a stop within 50 feet of the station with all rates and attitudes at or near zero.

Immediately upon completion of the rendezvous maneuver, the pilot received a visual presentation of the supply vehicle as it would appear to him standing off the station docking port. The presentation was accomplished through the use of closed-circuit television which assumed a camera located at the center of the docking port. The supply vehicle here was the General Electric Docking Simulator, Figure 10, which was operated remotely by the crew member using the same controls he had used to complete the rendezvous maneuver. This docking simulator, an air bearing device in five degrees of freedom, was then maneuvered by the crew-man into the docking port. Of particular interest here is the use of TV visual flight reference only for the performance of this maneuver. It is interesting to note that although the docking maneuver over this two-dimensional presentation system is more difficult than when the simulator is flown with the pilot inside, the maneuver can be accomplished and can be completed in good fashion with a high degree of repeatability.

The Libby, McNeil and Libby Company provided the complete food system for the 30 day test. The diet was primarily composed of freeze-dried food which is reconstituted by adding specific quantities of water, gently kneading the package and in some cases warming for a short time. All of the food provided was analyzed for caloric and mineral content and percentages of carbohydrates, fats and protein. Included in the diet were servings of lobster, crab, roast beef, lamb, a variety of vegetables, deserts and snacks. A number of dishes of this food were prepared for consumption in the zero-g environment by the addition of a sauce containing a colorless and tasteless gelatin, which holds the food together and retains it on a plate or on a fork without the assistance of gravity.

Food preference rankings were made by the crew for each food item of one meal per day for the duration of the test. In this manner a large amount of data concerning the preference of various types of food is available and can be used for structuring the food system chosen for the next test or for a space station program. The importance of food quality to morale was substantiated by the comments of the terranauts.

The crew performed according to the work/rest cycle shown on Figure 11. This schedule was developed during the 30-day test program and is different from the initial cycle developed for the test in terms of the amount of time required for sleep and the balancing of rest periods around the periodic need for food preparation, consumption, and personal hygiene.

During the first several days, the work load required of each man was extremely high with the result that little time was available for eating and personal hygiene, no time was available for rest, and only four to five hours per day remained for sleep. The result -- high exhaustion and loss of morale.

By reducing the data handling work load and allocating more time for sleep, crew effectiveness was restored and morale returned to an acceptable level.

The test was successfully completed on November 6, 1963. Although a wealth of test data exists, discussion of that which appears to be most significant to space station systems analysis design and operation is appropriate.

The work/rest cycle described above has been replotted and is shown on the crew activity apportionment chart, Figure 12. As shown here, each crew-man performed the functions indicated every day during the test. It is significant that of the 24-hour day only four hours per man were available for mission activities. Review of this chart highlights the problem involved in scheduling crew activities and developing a meaningful mission time allocation for crew complements of less than four men.

In the tasks of station management, including all those functions associated with operating the station, the crew performed as well during the last day as they did during the first day. Results of the rendezvous and docking performance indicated an initial difficulty during the first run on the part of each crew member. This difficulty was apparently caused by a loss of proficiency during the three-week period between the end of the rendezvous training and the first simulation in the cabin. This result seems to support the premise that some method of maintaining critical flight phase proficiency will be required on board, and that some time must be allocated for maintenance of this proficiency.

Included in the cabin equipment were several pre-failed electronic modules. Repair of these modules was required on a scheduled basis. In addition, seven unprogrammed failures of operating equipment occurred which demanded repair as soon as possible. In all cases, using schematics and standard checkout equipment the crew was able to trace the failure, effect the appropriate equipment repair, and prevent abort.

Of the eleven specific psychological tests conducted, no decrement of crew performance as a function of time was detected. Conversely, those tests associated with eye-hand coordination indicated a significant improvement in crew performance as a result of the crew's ability to compete one with the other in these particular tasks on a day-to-day basis. Of significance was the high day-to-day variability of the scores recorded during the vigilance tasks. This variability was strikingly large and has been correlated with subjective data gathered through the crew's diaries indicating a strong relationship between morale on any given day with performance of a task which required high concentration over a long period of time. The question one would ask at this time is the effect upon crew reliability during these periods of apparent depression. The answer is yet unknown but certainly indicates that the design of operating equipment must consider the danger associated or implied by these results.

Regarding possible tour-of-duty limitations, the relationship between crew members, as manifested in morale, may be an important factor. For this reason, measures of group cohesiveness were taken seven times during and several times before and after the test. The assessment of cohesiveness was based on a 24-item adjective rating scale which each crew member filled out ranking himself and the three other crew members. Each subject's ratings of psychological distance between himself and the other three crew members was pooled statistically in order to arrive at the measure of cohesiveness shown on Figure 13. As can be seen, the trend over the 30 days is progressively downward. While an acceptable lower limit cannot at this time be established, the possibility of eventual overt conflict is apparent. The rather sharp downward trend in cohesiveness can be partially attributed to the fact that little team performance was required, since most of the mission tasks are, by nature, individual efforts, and therefore, not conducive to development of crew esprit de corps. This explanation is verified by the daily diaries of the crew.

Also, related to tour of duty limitations are the test results associated with nitrogen metabolism. Here, measures of negative nitrogen balance, increased urine, creatinine, blood/urea/nitrogen, coupled with a loss of muscle tone indicates a definite loss of muscle protein and tolerance to exercise. As a result, a daily exercise regimen for future tests, increased substantially for orbital operations while weightless, is indicated. Once again this requirement will have the effect of subtracting from the useful time available for performing mission tasks.

As discussed above, the choice of 7 psia atmosphere (360 mm Hg) was the result of a design study which quantitatively evaluated structural weight penalty, fan power requirements, leakage, purge, and air lock losses. The curve shown on Figure 14 is the result of these trade-offs applied to a four-man space station. As indicated, the 7 psia atmosphere permits a total systems weight reduction of 860 pounds as compared with a sea-level environment. Not only is this weight reduction significant, but in addition the 7 psia environment provides the crew with greater protection from aero-embolism which might possibly be induced by a cabin decompression. It also eliminates the need for the critical time requirement for denitrogenation prior to the use of a pressure suit for extra vehicular operations. These considerations suggest a minimum pressure level of approximately 6 psia. However, the concern for the fire hazard problem associated with high oxygen concentrations is real. The compromise, therefore, between a minimum-weight 6 psia system and one which is reasonable from the fire hazard standpoint appears to be on the order of 7 psia (50% oxygen - 50% nitrogen). While desirable from an engineering standpoint, evaluation of the possible physiological effects upon the crew of long exposure to this environment was necessary.

The measures which were made upon this crew were indicated on Figure 8. The results of these measures shown on Figure 15, grouped by function, indicate completely normal physiological response throughout the 30-day period. All measures taken were in all cases within normal clinically acceptable tolerance limits and could not be considered significant in any respect.

In the operational sense, exposure of test monitors 180 times to the 2.2 critical range of decompression during this test, validated the assumption that problems associated with aero-embolism will not exist if this atmosphere is used. Faulty equipment caused a fire during a pre-test checkout run. This fire was electrical in nature but was easily extinguished using standard fire fighting equipment. This experience also tends to justify the choice, from an operational and safety standpoint of the 7 psia atmosphere.

Of interest to the design of life support equipment are the results associated with the water-balance measures taken. In this particular environment Figure 16 indicates a large increase in sweat and respiration water loss, with a corresponding decrease in urine and fecal water discharge. Of interest also are the critical remarks made by all the crew at a debriefing wherein they indicated a constant feeling of dryness although the humidity level was maintained between 35 and 40 per cent.

The volume of the cabin tested is shown on Figure 17. In all cases the crew reported a complete feeling of adequacy for the duration of the test. Furthermore, it is suspected that this same cabin with only minor modifications could support a six-man crew as well as it housed the four. In terms of arrangement, it was obvious that provisions for individual privacy would be highly desirable and should be considered a design goal. This desire plus the need for increased flexibility of the living compartment indicates a sound and light isolation requirement for the sleeping compartments.

The food which was supplied appear to be an extremely important benefit to the test subjects. Several of the crew indicated that a good meal at the end of their day was anticipated and also looked upon as a reward for their activities and performance. Food preference charts were kept current and are shown on Figure 18. Food preference six is equivalent to "like moderately" while eight is "like extremely". The three day gap shown represents that time when the crew used a pureed food form. Although food preference data was not taken during those three days, the almost unanimous comment was that the food was less desirable than the maximum acceptability diet. In terms of weight, the maximum acceptability diet which was used weighs no more than the squeeze diet sometimes recommended for space flight. The only penalty which is paid, as the lower curves indicate, is the volume required for storage. The trade-off, therefore, becomes a simple one between the volume available and the volume needed to provide this highly desirable food form.

In summary, the results of this test indicate that men can perform adequately for a thirty day mission, that group cohesiveness degraded significantly, that the men showed a definite loss in muscle tone, that 40% relative humidity in the selected atmosphere is too low, that rendezvous and docking can be successfully performed using conventional aircraft-type controls and visual contact, that the effects of the selected atmosphere had no deleterious physiological results, and that freeze-dried foods are highly acceptable and desirable. The cabin arrangement was found generally acceptable. Changes in the work/rest cycle were found necessary after about four days because inadequate time was left for sleeping. Adjustment to schedule that allowed about six hours of sleep daily permitted all tasks to be successfully performed and morale and motivation to rise to a high level for the remainder of the test. Pre-failed panels as well as some unprogrammed failures were successfully repaired with the few tools brought on-board and with a minimum of pre-test instruction as background. At no time was there a threat of abort.

Results also indicated that the four hours per day of mission time per man could be increased by applying more automation to the subsystems monitoring and data handling aspects of the flight. Since any increase in mission time availability is reflected in increased data return, this aspect of station system design and operation is highlighted. This is particularly true if a two-man system is contemplated or if any degree of flexibility to meet unusual or emergency situations is to be realized.

In light of these results, the fundamental assumptions around which this test program was structured appear to be substantiated. First, that a high fidelity mission simulation conducted early in the design phase of manned space vehicles systems is invaluable in providing basic validation of assumptions and development of criteria upon which a system can be analyzed and designed. Second, the use of this type of simulation for the development of specific mission systems operations, crew size and equipment requirements is mandatory for efficient development of specific manned space station systems. Finally, this work has substantiated the introduction of the basic crew utilization considerations such as mission time availability and overall effectiveness as being as fundamental to space station design and as quantifiable as weight, power, volume, and cost.

MANNED MISSION TESTS

	SPACE CABIN TESTS	POSSIBLE FUTURE SPACE CABIN TESTS
STATIC:		
DETECT SURFACE TARGETS	X	X
IDENTIFY SURFACE TARGETS	X	X
INTERROGATE BUOYS		X
TRACK SURFACE TARGETS		X
STATIC AND DYNAMIC:		
DETECT SPACE VEHICLES		
TRACK SPACE VEHICLES		
OPERATE MISSION EQUIPMENT	X	X
SELECT SENSORS, MODES, ETC.		X
ORIENT VEHICLES	X	X
ANALYZE MISSION DATA		X
PROGRAM MISSION		X
TRANSMIT REPORTS		X
DYNAMIC:		
IDENTIFY SPACE VEHICLES		
OPERATE SEARCH EQUIPMENT		
LAUNCH VEHICLES		
RECOVER VEHICLES		

Figure 1 POSSIBLE MANNED MISSION TESTS

SUBSYSTEM TESTS

EQUIPMENT	MAN'S TEST FUNCTIONS	SPACE CABIN TESTS	POSSIBLE FUTURE SPACE CABIN TESTS
STATIC:	ASSEMBLE EQUIPMENT		X
CAMERA	ALIGN, TUNE EQUIPMENT	X	X
RADAR	OPERATE EQUIPMENT	X	X
INFRARED	VARY EQUIPMENT PARAMETERS		X
TELESCOPE	REPAIR EQUIPMENT	X	X
OTHER	EVALUATE TEST DATA		X
DYNAMIC:	REDIRECT TESTS	X	X
TRACKING RADAR	REPORT RESULTS	X	X
PROBE VEHICLES			
TARGET VEHICLES			
SPACE PROPULSION			
OTHER			

475

Figure 2 MANNED SUBSYSTEM TESTS

SIMULATION PARAMETERS

- **ENVIRONMENT**

 - GASEOUS

 - CONFINEMENT

 - CREW EQUIPMENT

- **DURATION**

 - MISSION DEPENDENT

- **CREW ACTIVITY**

 - WORK / REST CYCLE

 - MISSION PROFILE AND TASKS

 - MISSION TASKS

 - EMERGENCY CONDITIONS

 - MAN-MACHINE INTERFACE

Figure 3 SIMULATION PARAMETERS



Figure A OVERALL VIEW - SPACE STATION SIMULATOR

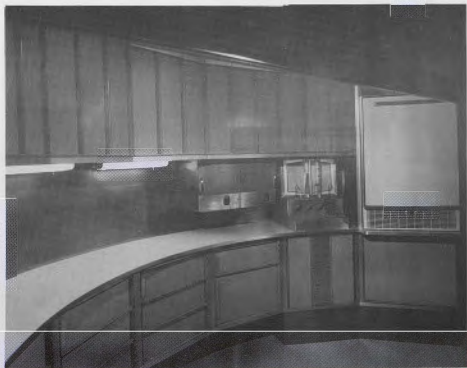


Figure 5 LIVING COMPARTMENT - FOOD STORAGE AREA

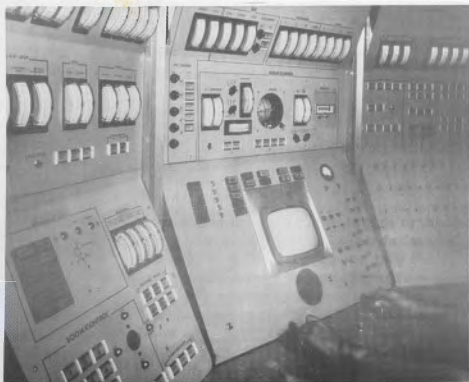


Figure 6 SPACE CABIN INSTRUMENT PANEL

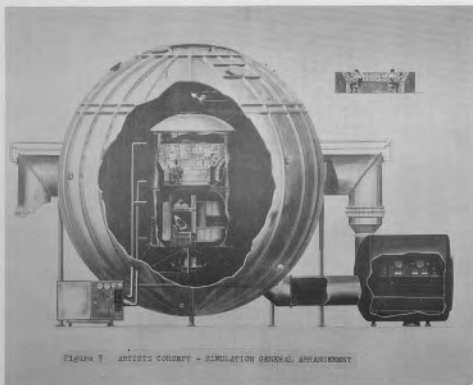


Figure 7 ARTIST'S CONCEPT - SIMULATION GENERAL ARRANGEMENT

PREFLIGHT/POSTFLIGHT STUDIES

BASIC CLINICAL STUDIES

**HEMATOLOGY - Hb, HEMATOCRIT, RbC, WbC, DIFF. PLATELETS,
RETICULOCYTES**

URINALYSIS - SpG, ALBUMIN, SUGAR, ACETONE MICROSCOPIC

**BLOOD CHEMISTRY - BLOOD SUGAR, BUN, CREATININE, Na⁺, K⁺, Cl⁻
CALCIUM, PHOSPHOROUS, PLASMA CATECHOLAMINES**

**URINARY CHEMISTRY - VOLUME (24 HR), OSMOLARITY, Na⁺, K⁺, Cl⁻,
NITROGEN, Ca⁺⁺, PHOSPHOROUS, CREATININE,
CATECHOLAMINES, 17 - HYDROXYSTERIODS**

BACTERIOLOGY - FECAL, PHARYNGEAL, SKIN AND URINARY

ECG

CHEST X - RAY

OPHTHALMOLOGICAL EXAM PERIMETRY

AUDIOMETRY

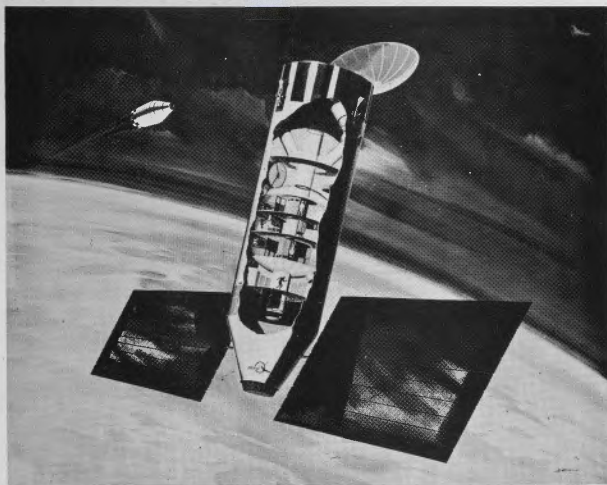


Figure 1. LARGE ORBITING RESEARCH LABORATORY

[illegible]

Figure 11 FINAL CREW WORK/REST CYCLE



R. E. JOHNSON

Position:
Company:
Education:

Engineering Specialist
Sylvania Electronic Systems, Williamsville, N.Y.
B.S., Physics, Wisconsin State College
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Experience:

Sylvania Electronic Systems Division Atmospheric
Millimeter wave propagation, Electronically
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Martin-Marietta Corp. - The Martin Company
Division, Orlando, Florida, 1958-1963. Senior
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Goodyear Aircraft Corp. - Engineer to Senior
Engineer, 1955-1958. Research, development,
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BIOGRAPHICAL SKETCH NOT AVAILABLE



T. E. WOLK



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Post graduate research in electrochemistry in
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E. DOUGLAS DEAN



HUGH LENNEOUS COX

B.C.E., North Carolina State College, 1949; M.S., Civil Engineering, University of Illinois, 1952; Ph.D., Structural Engineering and Applied Mechanics, University of Illinois, 1953.

Joined Martin Company, Denver Division, in 1959. Currently Chief, Structures and Aerophysics Technical Development. Previously served as Initial Head of Technical Development for Silo Launch Test Facility and Technical Director of Complete Titan II Shock Isolation System.

Employed by Kirk Engineering Company (1956-1959) as Consultant to the Martin Company.

Structures and Dynamics Engineer, Army Ballistic Missile Agency, 1955-1956.

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Structural Engineer, Douglas Aircraft Company, Santa Monica, California, 1953-1956.

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B.S. in Aeronautical Engineering, University of Kansas, 1949.
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Mr. Winter has been employed since 1957 as a Group Engineer with the Martin Company, Denver. Analysis and test of Titan II Thrust Mount and Shock Isolation System; Titan I Open Base Shock Mounting Inspections; Inflatable Structures Study.

He was previously employed as Stress Engineer, Emerson Electronic Mfg. Company, Electronics & Avionics Division, St. Louis (November 1954 to September 1957).

Mr. Winter taught at Washington University, St. Louis, Missouri, from June 1954 to October 1954.

He was associated with Sverdrup & Parcel Inc., St. Louis, Missouri, as a Designer-Detailer (August 1953 to May 1954).

He is a member of the American Institute of Aeronautics and Astronautics, Tau Beta Pi and Sigma Tau.



RALPH O. WINTER



T. CHARLES HELVEY

Completed doctoral thesis in physical chemistry at Kaiser Wilhelm Institute in Berlin, majoring in chemical engineering. Worked at Medical School of University of Halle (Germany), attended Institute of Nuclear Studies at Oak Ridge. Research associate at Cornell University and University of Miami Marine Laboratory. Associate professor at Oneonta College of New York State University. Joined Research Institute of Advanced Science in Baltimore, subsequently the Human Factors Section of the Martin Company, and headed Environmental and Dynamics Laboratories, Orlando Division.

Visiting professor of biophysics at Radiation Biophysics Department of Kansas University. Director of Biophysics and Astrobiology Branch, Radiation, Inc., Research Division, Orlando; Chief Scientist of Ortronix, Inc., Orlando. In 1960 accepted associate professorship in Biological Sciences at University of South Florida.

Executive Secretary of the Tampa Bay Area Council of Aging, Director of Inter-American Institute for Space Science Education. Author of sixty-two scientific articles and several books.

Mr. Lang received his Bachelor of Mechanical Engineering Degree from the City College of New York in 1955. Upon graduation he joined the Research Division of the Curtiss-Wright Corporation and worked principally on the development of advanced jet engine concepts. In 1959 he became affiliated with the Hamilton Standard Division of United Aircraft Corporation. He was given technical responsibility for the analysis and development of a solar thermoelectric power generator for space use which was designed, built and tested successfully within 1 1/2 years. At present Mr. Lang is a System Analyst in the Space Suit Group. His principal responsibility is the performance of optimization studies leading to the development of low weight, small volume, high reliability life support systems. Important among these are the analyses necessary for providing adequate thermal, contaminant, and pressure control. In addition he has coordinated the task of physiological monitoring and evaluation of test data during manned testing.



RONALD LANG

Present Position: Chief, Life and Environmental Systems Section, Advance Space Technology. Directs Advanced Design of Power Systems, Environmental Control and Life Support Systems and Vehicle Safety Systems.

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Professional Activities: Director of Southern California ASME Aviation and Space Division, 1960-62; member ASME Professional Division Council, ASME Space Division National Executive Committee (Secretary), ASME National General Committee for Spacecraft, and Institute of Environmental Sciences.



T. C. SECORD

Dr. Yarymovych is Acting Director of Manned Earth Orbital Mission Studies, Advanced Manned Missions Program in the NASA Headquarters Office of Manned Space Flight. He is responsible for the development of the NASA program for advanced manned earth orbital systems, including space stations.

He was previously Assistant Director of Systems Engineering, Flight Systems, in the NASA Office of Manned Space Flight, responsible for systems engineering of various subsystems of the Apollo spacecraft and launch vehicle.

Dr. Yarymovych came to NASA from Research and Advanced Development Division of Avco Corporation, where he was Manager of Nuclear Electric Systems. His industrial experience was preceded by research activities at the Institute of Flight Structures of Columbia University.

He received his B.S. Degree in Aeronautical Engineering at N.Y.U. His M.S. and Ph.D. Degrees in Engineering Mechanics were earned at Columbia University.



MICHAEL I. YARYMOVYCH



RICHARD A. PASSMAN

B.S.E. in aeronautical Engineering and B.S.E. in Mathematics from University of Michigan, 1944. Later, upon discharge from the Navy, was employed as an engineer with Grumman and Consolidated Vultee Aircraft.

In 1947, he received his M.S.E. in Aeronautical Engineering from the University of Michigan.

Was project aerodynamicist at Bell Aircraft Corporation from 1947 to 1956. Projects included the experimental rocket aircraft X-1 and X-2, work on Rascal and Meteor missiles. He joined the General Electric Company in 1956 as project engineer for advanced nose cone systems.

In 1958, was given responsibility for all preliminary re-entry vehicle design. In this capacity the initial designs for Skybolt and Mark 6 were developed. In 1960, he was responsible for Advanced Systems Engineering. In 1961, he was appointed Manager of Advanced Engineering.

His current position is Manager of Advanced Systems Engineering for the Missile and Space Division.

Senior Flight Surgeon in the USAF Specialty Training Program in Aviation Medicine. Assigned for duty with the Deputy for Bioastronautics, AFMTC.

B.S. from Furman University, Greenville, South Carolina, 1949. M.D. from Medical College of South Carolina, 1954. Interned at Methodist Hospital in Gary, Indiana; entered Air Force in 1955.

Completed Primary Course in Aviation Medicine at Randolph AFB, Texas; assigned to Shaw AFB. Was Base Flight Surgeon and Commander of the 363rd TAC Hospital, and later Chief of Professional Services, Office of the Surgeon, Headquarters Ninth Air Force.

Upon completion of training program in radiobiology, was assigned to Office of the Command Surgeon, Air Defense Command, Ent AFB, Colorado, as Chief of Nuclear Medicine.

Received Master of Public Health Degree from Johns Hopkins University in 1962. Assigned to present duty in July 1963.



WILLIAM B. DYE



RAYMOND L. ALLEN

Raymond L. Allen is project engineer on the Dynamic Test Program at Thiokol Chemical Corporation's Wasatch Division, responsible for all interdepartmental technical coordination associated with the installation of Thiokol's new vibration facility and accompanying test program.

He joined the Wasatch Division as an instrumentation and test staff engineer in December 1959. In March 1960, he was promoted to group leader of the Instrumentation and Test Staff. Prior to his present position he served as an assistant project engineer in the Rocket Design Department. Served as a power plant associate engineer at Douglas Aircraft Co., Inc. and as an engineering aide at Aerojet General.

In 1957, Mr. Allen received his B.S. Degree in aeronautical engineering from California State Polytechnic College. Completed a Complex Vibration Seminar in July 1960 at MB Electronics, New Haven, Connecticut; presently studying to earn a master's degree in engineering administration from the University of Utah.

Leonard G. Flippin is associated with the Wasatch Division of Thiokol Chemical Corporation. He has worked with structural dynamics and the mechanics of materials in the Applied Studies Department for three years.

Prior to joining Thiokol, he served four years as a senior structures and dynamics engineer and 13 years as a civil and architectural engineer at Lockheed Aircraft Corporation. Was a senior structures engineer at U.S. Bearing Corporation for one year and a design specialist at Chrysler Corporation's Missile Division for 1 1/2 years.

Mr. Flippin earned his B.S. Degree in Civil Engineering from Lawrence Institute of Technology, Detroit, Michigan in 1949. During World War II he served as a pilot in the United States Air Force. He is a member of Aircraft Owners and Pilots Associates.



LEONARD G. FLIPPIN



A. H. S. CANDLIN

Taught at Northampton College of Advanced Technology (England). Is at Jacksonville University, Jacksonville, Florida, in the Division of Science and Mathematics, and is lecturing to physics seniors on nuclear physics.

Until the beginning of 1960, was on the scientific staff of England's Ministry of Defense and held a series of official appointments within the Defense field, which included wartime service with the Government of India, totalling about fifteen years. At the end of his service in these capacities was engaged part time in space matters.

B.S. in Electrical Engineering, University of Manitoba, Winnipeg, Canada, 1949; Graduate School, Case Institute of Technology, Cleveland, Ohio, 1950. Full M.S. Curriculum less Thesis.

Television Technician Training, Television Training Institute, Philadelphia, Pennsylvania, 1942 (approximately one year). Color Television Training, RCA Institute Home Study Course, 1954.

Radio Operator & Mechanic's School (USAF). Specialist's Training in V.H.F. Receivers and Transmitters (detached service with Royal Air Force).

Employed since 1963 as Department Manager of Quality Systems Engineering, Martin Company, Baltimore. Previous employment with Martin (since 1955) included positions as Quality Manager on Vanguard Program, Titan I Field Crew Effort, Dynasoar Booster Program, and Gemini Launch Vehicle Program.

Numerous speaking engagements at Technical Society Meetings, ASQC Conventions, Canadian Aeronautical Institute, etc.



HAGGAI COHEN



L. H. KRATZER

B.S., Mechanical Engineering, University of Utah, 1950. M.S., Physics, University of Utah, 1952.

In charge of the Instrumentation Development Lab, Dugway Proving Ground, 1950-1952. Supervised developmental activities and directed field testing programs on micro-meteorological instruments and air sampling devices at Stanford University, 1952-1957.

While a Senior Scientist in R&D, Lockheed Missiles & Space Company, he designed the inertial reference package of the Agena Vehicle. As Research Specialist, he established and directed the operation of a Reliability Diagnostic Laboratory and served as environmental consultant.

In his capacity as Technical Test Director, HIVOS Facility, Mr. Kratzer supervised the activities of up to 65 engineers and technicians.

B.S., Mechanical and Electrical Engineering, 1931, Harbin Polytechnic Institute, Harbin, China; M.S., Mechanical Engineering, 1932, University of Michigan; Ph.D., Mechanical Engineering, 1935, University of Michigan.

Designer and Draftsman, Economy Baler Company, Ann Arbor, Michigan, 1935-1936. Instructor, Fenn College, Cleveland, Ohio, 1936-1940. Acting Head, Mechanical Engineering Department, Fenn College, 1940-1944. Project Engineer, Thompson Aircraft Products, Cleveland, Ohio, 1944-1945. Acting Head, Fenn College Mechanical Engineering Department, 1945-1946. Senior Industrial Engineer, Kenneth A. McIntyre Associates, Cleveland, Ohio, 1946-1947. Aeronautical Research Scientist, NACA, Lewis Laboratory, Cleveland, Ohio, 1947-1953. Design Specialist, Hydro-Aire, Inc., Burbank, California, 1953-1954. Engineering Specialist, Northrop Aircraft, Inc., Hawthorne, California, 1954-1957.

Joined Lockheed Missiles & Space Company in 1957. Currently Senior Staff Engineer, serving as consultant to laboratory engineers.

(Picture Not Available)

VASILY D. PRIAN

Graduated from M.I.T. in 1959 with a B.S. in Optical Physics. In January of 1958, he started half-time employment with Block Associates, Inc., of Cambridge, where he worked on a metrological interferometer and design and fabrication of infrared spectro-radiometers. Also during his years at M.I.T., he was responsible for the operation and maintenance of the Color Measurements Laboratory of M.I.T.

Joined the Research Laboratories of United Aircraft Corp. in February of 1960, where he developed automated lens design and evaluation programs using 7090 computers.

Mr. Willey went into full time activity in his own company, Willey Optical Research Lab and Development Service (WORLD'S, Unlimited), in July of 1962. WORLD'S was engaged in engineering, lens design, and prototype fabrication.

In July of 1963, WORLD'S was purchased by the Instrument Corporation of Florida and Mr. Willey assumed the directorship of their combined optical activities.



RONALD R. WILLEY, JR.



HAROLD L. JURY

Presently the Project Manager of Advanced Geodetic Survey Projects for Pan American World Airways at the Atlantic Missile Range, Mr. Jury holds a B.S. Degree in Geology from Syracuse University and a M.S. Degree in Photogrammetry and Geodesy from Ohio State University. While completing graduate studies at Ohio State, he served as a research fellow doing photogrammetric research in Greenland.

Mr. Jury worked three years with the Inter-American Geodetic Survey in Central and South America, performing various types of surveys and training Latin engineers in the sciences of geodesy and photogrammetry.

During World War II, he was a combat navigator on B-29 aircraft in the Pacific and presently holds a reserve commission in the United States Air Force. He is a member of the American Society of Photogrammetry and the American Institute of Aeronautics and Astronautics.

Dr. Siegmund was born in Germany but emigrated to the United States in 1930. He grew up in Rochester, New York and pursued his undergraduate and graduate studies at the University of Rochester, where he received his Ph.D. degree in 1952.

After a year of post-doctoral work at Rochester he joined American Optical Company in 1953 as a member of its Research Department staff. He became Assistant Director of Research in 1958, a position he held until December 1963, when he became Manager of the Fiber Optics Department of the Space Defense Division.

(Picture Not Available)

WALTER P. SIEGMUND



THOMAS J. HAYES III

Thomas J. Hayes III, son of Major General and Mrs. Thomas J. Hayes (USA-ret), was born 26 August 1914 in Omaha, Nebraska. A graduate of the U.S. Military Academy at West Point (Class of '36) with a Master of Science Degree from MIT (1939). Also a graduate of The Engineer School, the Command and General Staff College, and the Industrial College of the Armed Forces.

His 27-year career in the Army Engineers has been a varied one. In addition to troop duty with Engineer units at home and abroad, he has served on the faculty of The Engineer School, Fort Belvoir, as Engineer Liaison Officer to the British Army, Assistant Military Attache in London, and Assistant Engineer Commissioner of the District of Columbia.

General Hayes was in charge of the \$1.7 billion construction program developing the nationwide network of intercontinental ballistic missile bases for the Air Force, and two years ago was selected to head the Corps of Engineers' activities supporting the NASA Manned Space Program.

Born in Scranton, Pennsylvania, August 18, 1911. Graduated from Scranton Technical High School in 1932; received B.S. in Economics from the University of Notre Dame in 1936. Entered New York University Law School, receiving his L.L.B. in 1940.

After practicing law in Elizabeth, New Jersey, was counsel for the U.S. House Committee on Administrative Law. After the War, served as counsel to the U.S. Senate Small Business Committee, and later as a Production Analyst for the U.S. Navy in Washington.

Joined Bogue Electric, Inc., Washington, D.C., as Vice President in charge of production. In 1955, became Senior Management Consultant for Wellings-Reed, Inc., Washington, D.C. Remained with this firm until 1960; accepted a position with the Federal Aviation Agency, continuing with this agency as Management Analyst Supervisor until 1962. Currently Chief, Management Analysis Office, Executive Staff, of the George C. Marshall Space Flight Center, Huntsville, Alabama.

(Picture Not Available)

JOSEPH H. REED

Ben W. Brion was graduated with a Bachelor of Science Degree in Electrical Engineering, major in Communications, from Purdue University in 1937.

Prior to World War II he worked as a field engineer testing gun control prototypes for Sperry Gyroscope. During the war he moved to Minneapolis Honeywell where he designed military and commercial control systems.

In 1947, with the Engineering Research Division of Remington Rand, he served as Project Engineer on that company's first electronic digital computer. From Remington Rand he moved to the Mechanical Division of General Mills, where he held the position of Chief Electrical Engineer for eight years.

In 1958 he started his own company, the Brion Engineering Company, where he engineered and marketed two products.

Brion is presently a Senior Staff Engineer with General Electric's Apollo Support Department in Daytona Beach, Florida.

(Picture Not Available)

BEN W. BRION



C. D. SCHWEBEL

Employed by the Martin Company Canaveral Division as a mechanical systems engineer assigned to the Titan III Project. Formerly Senior Staff Engineer in the Ferrite Components Section of Sperry Microwave Electronics Company in Clearwater, Florida.

Was employed as a Registered Professional Engineer in Chicago until moving to Florida in 1957. Educated at Illinois Institute of Technology.

Frank B. Page, Ph.B., Yale University, 1931, taught engineering at the University of Rochester, and was an engineer at Pratt & Whitney Aircraft, at Brookhaven National Laboratories, and at General Electric.

While teaching, he served as consultant to General Motors on aircraft powerplant controls. He joined G.E. in 1953 as an engineer in the General Engineering Laboratory, where he did development work in pumping and propulsion systems; served the Small Aircraft Engine Department as a reliability engineer.

In 1962 he joined the Apollo Support Department, and was assigned to Huntsville, where he laid the groundwork for current G.E. reliability support at Marshall Space Flight Center. He is co-holder of two patents, and author of a number of G.E. technical reports.

He is a member of ASME, ASEE, and a charter member of the Daytona Metropolitan Section of AIAA.

(Picture Not Available)

FRANK B. PAGE



GEORGE E. HENRY

George E. Henry, A.B., University of North Carolina, 1945, has been with General Electric since 1948, first as a member of the General Engineering Laboratory in Schenectady, later as manager of Reliability for Ordnance Department in Pittsfield.

He joined the Apollo Support Department in 1962, and has done development work in acoustics and electrical controls. Holds a number of patents, has been active as a lecturer and teacher of Company-sponsored courses. Has written for G.E. Review, Scientific American, and the new Grolier Encyclopedia. Is a charter member of the Daytona Metropolitan Section of AIAA.

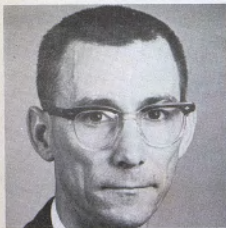
Mr. Zachmann has more than 20 years experience in electric motors and power systems. Since joining Martin in 1951, he has served as consultant on electric motor applications, power systems, batteries and electromechanical actuators. Most recently, he has been active in the design of electrical power systems for space and lunar applications.

Prior to joining Martin Marietta, he has worked in a wide variety of industries. He has acquired a depth of experience in research, development, design and application of electric power equipment including rotating machines, turbo-alternators, transformers, switch gear, batteries and electromechanical devices. His numerous papers qualify him as an authority on aerospace electrical systems.

A native of New Jersey, he holds a B.S. in Electrical Engineering from Newark College of Engineering and is a registered Professional Engineer in the states of New York and Pennsylvania.

(Picture Not Available)

HOWARD G. ZACHMANN



DARREL G. HARDEN

Assistant Professor of Mechanical Engineering at the University of Oklahoma, Norman, Oklahoma. Teaches and researches in the heat transfer-fluid flow-thermodynamics area.

Head, Department of Mechanical Engineering, Oklahoma State University, Stillwater, Oklahoma. Administers large graduate and undergraduate program at Oklahoma State. Active in all phases of heat transfer research.

(Picture Not Available)

J. H. BOGGS



DAVID K. BARTON

David K. Barton was born in Greenwich, Connecticut, in 1927. He received the B.A. Degree in Physics from Harvard College in 1949.

From 1949 to 1953 he worked as an electronic engineer with the White Sands Signal Corps Agency. From 1953 to 1955 he was a project engineer in Evans Signal Laboratory, Belmar, N.J., responsible for development contracts on radar beacons and related equipment. Between 1955 and 1963 he was a systems engineer with RCA Missile and Surface Radar Department in Moorestown, New Jersey.

In 1958 he received the David W. Sarnoff Award for outstanding achievement in engineering, based upon his contributions to precision tracking radar. In 1963 he joined the Raytheon Company at Wayland, Mass., as a staff engineer. Has presented papers at national conventions and symposia, was a lecturer at the 1960 and 1961 Special Summer Course in Modern Radar Technique at the University of Pennsylvania.

Edward Heinzerling received his B. Degree in Electrical Engineering from Tufts College in 1951. From 1951 through 1954 he served as an Electronics Officer in the U.S. Navy.

In 1956 he received the M.S. and E.E. Degrees in Electrical Engineering from the Massachusetts Institute of Technology. Since 1956 he has been with the General Electric Company, Syracuse, New York, where he specialized in the analysis and evaluation of missile radio guidance and tracking equipment.



EDWARD HEINZERLING



J. N. STRAND

Mr. Strand is employed by General Electric in their Radio Guidance Operation. He has been employed by them for the past three years as a Mod III Radar Systems Evaluation Engineer and has completed the National Bureau of Standards 1962 course in Radio Propagation.

For the past two years he has been evaluating the effects of the troposphere upon noise in radar data from Mercury, Ranger and Mariner missions. Previously, he was employed by Boeing Airplane Company as a test planner for the radio controlled Bomarc. Mr. Strand graduated from Illinois Institute of Technology in 1956 with a B.S. in Chemical Engineering. He is a member of the American Ordnance Association.

Personnel Psychologist with fourteen years experience in industry. Completed M.A. in Psychology at Fordham University in 1951 and Ph.D. in Industrial Psychology at Western Reserve University in 1956.

Work centered on executive evaluation and management development. Having formerly worked in the consulting field, now serving as Director, Personnel Planning, Development, and Training with ITT Federal Laboratories.

Member of American Psychological Association and author of several articles in professional and management periodicals.



ARTHUR D. KELLNER



RICHARD G. LAZAR

Mr. Lazar is a Personnel Development Specialist with ITT Federal Laboratories, a multi-plant electronics R&D operation of 5,000 people. In this capacity he is responsible for management development activities, which include performance appraisal and individual development, maintenance and operation of the company skills inventory, test evaluation, personnel research and control of turnover. Prior to his present position, Mr. Lazar worked for 5 1/2 years in Human Engineering.

He received his B.B.A. Degree in Industrial Psychology in 1956 from CCNY and his M.A. Degree in Psychology from Syracuse University in 1957. He is currently working for a Ph.D. at NYU.

Laurence W. Enderson, Jr. is an Aerospace Engineer in the Mission Analysis Section of the NASA Langley Research Center. He is currently doing research in Space Mechanics on problems associated with manned space exploration. Prior to this he was employed by the NASA Manned Spacecraft Center in the Mercury Project Office.

(Picture Not Available)

LAURENCE W. ENDERSON, JR.

(Picture Not Available)

William H. Michael, Jr. is head of the Mission Analysis Section at the NASA Langley Research Center. His research interests have included trajectory analysis for manned and unmanned lunar missions, feasibility studies for experiments in space exploration, and studies in celestial mechanics.

WILLIAM H. MICHAEL, JR.

Gordon D. Thayer was born October 24, 1931, at Glen Ridge, New Jersey. He attended Cornell University (1949-1951) as a math major; Newark College of Engineering (1954-1955), M.E. major; and the University of Colorado (1955-1957), receiving a B.S. Degree in Engineering Physics June 9, 1957.

Joined Boulder Laboratories, National Bureau of Standards, June 17, 1957. Presently with the radio-meteorology group, his projects with NBS include tropospheric analysis, mathematical analysis and data reduction, research on problems of tropospheric refraction and attenuation of radio signals.

Prior to joining NBS, Thayer was employed as a Chemistry Laboratory Aide at the Cathode Ray Tube Division of Allen B. Dumont Labs., Allwood, New Jersey, and as Instrument Calibrator and Checker at Weston Elec. Instr. Corp., Newark, New Jersey. While in the U.S. Army Signal Corps, he was at White Sands Proving Ground and at Evans Signal Lab, Belmar, New Jersey.

(Picture Not Available)

GORDON D. THAYER

Born in Chicago, Illinois, 1920. B.S. in Electrical Engineering, University of Southern California, 1944; M.S. in Electrical Engineering, University of Southern California, 1950.

Was with Lockheed Aircraft Company in their Experimental Flight Division while earning his B.S. Degree. Commissioned as Ensign, USNR, in August, 1944, and assigned to the Aircraft Electrical Division of the Naval Research Laboratory in Washington, D.C. Returned to the University of Southern California in July, 1950, where he was Head of Evaluation for the Guidance and Control Department until December, 1954. Joined Lockheed Missile System Division in Van Nuys, California.

In 1958 he returned to Hughes Aircraft Company, in the MG Series Fire Control Systems Department. Joined the Reliability and Systems Test Department of the Surveyor Spacecraft Laboratory in 1960; currently Assistant Manager of the Surveyor Systems Engineering Department.



ARTHUR A. DAUSCH, JR.